Empirical explorations of firm innovation, government intervention and firm performance in European countries

Crowley, Frank

Chapter Three

3. INNOVATION AND PRODUCTIVITY IN IRISH FIRMS

ABSTRACT

This paper uses an endogenous switching technique which allows us to utilise micro-econometric data allowing us to construct counterfactual scenarios of the innovation-productivity relationship in Irish firms. A firm's innovation effort, capital intensity, firm size, location and its operating environment are key variables in explaining a firms' propensity to innovate. However, the importance of these factors differs across innovation types. We find mixed results on the effect of innovation on the productivity of innovators across innovation types. The results indicate in the counterfactual analysis that all types of innovation have a positive effect on the productivity levels of non-innovating firms.

Keywords: innovation; productivity; endogenous.

JEL classification: 031, 032.

3.1 | INTRODUCTION

Innovation is critical for economic development (Schumpeter, 1942, Romer, 1990). This paper focuses on the innovation production and exploitation stages of Irish firms. We introduce a novel approach by employing an endogenous-switching technique which allows us to utilise micro-econometric survey-based information from both innovating and non-innovating firms, and these techniques thereby allow us to construct counterfactual scenarios which overcome problems of self-selection in the data. A number of key dimensions of the innovation-productivity link are explored. Firstly, we explore the importance of firm characteristics for the innovation performance of firms. Secondly, we explore how important different types of innovations (product, process and organisational innovation) are for a firm's productivity and finally, a key focus of this paper is to discover the returns to innovation for innovators and non-innovators.

Early work on the sources of productivity growth focused principally on the role of capital and labour. However, in recent decades much of the attention has focused on the unexplained element of the Solow growth residual, known as technical change or innovation. Much of the focus in the literature over the past few decades has attempted to measure and explain how innovation occurs and the effects of innovation on the productivity of firms (Crepon *et al*., 1998, Doran and O'Leary, 2011, Griffith *et al*., 2006, Roper *et al*., 2008). In terms of understanding how innovation occurs, two principal related lines of enquiry are pursued: what types of firms are more likely to innovate? And, what role does economic geography play in influencing the innovative performance of these firms? (Simonen and McCann, 2008).

The role of firm's characteristics and its effects on the innovation performance of firms has been a popular avenue of enquiry. This perspective takes a resource-based view of the firm where each firm possesses a unique set of resources and capabilities, resulting in varying innovation success. The second perspective focusses on the significant role of agglomeration economies in fostering localized learning processes within the economy and this perspective has long been established in the theoretical literature (Glaeser, 1999). From the empirical analysis completed in the innovation-productivity area, it is evident that the sources of innovation are varied and this may be due to a number of different reasons such as the changing measures of innovation employed in different survey methods such as new to market innovation versus new to firm innovation, resource differences of firms and the complexity of the geographical environment (Vega-Jurado *et al*., 2008, Souitaris, 1999).

In terms of understanding the innovation-productivity relationship, there is conflicting evidence around the benefits of innovation for the success of the firm. The theoretical literature argues that innovation is essential for economic progress (Schumpeter, 1942, Romer, 1990, OECD, 2011) However, the evidence on the benefits of innovation for labour productivity are not definitive. Some studies have found innovation indicators to have a positive effect on productivity (Griffith *et al*., 2006, Lööf and Heshmati, 2006, Mairesse and Robin, 2009) but some studies have found innovation indicators to have a negative effect on productivity (Roper *et al*., 2008). We employ an endogenous switching model to explicitly examine the importance of the self-selection mechanisms in innovation by exploiting the information derived from non-innovators as well as innovators.

This paper uses the 2005 Irish Business Environment and Enterprise Performance Survey (BEEPS). This data set contains a rich detail of micro-data at the firm-level. The use of the BEEPS data provides us with an opportunity to analyse innovation and productivity as a function of firm-specific characteristics. Three different innovation output variables are used in this study that represent new and improved products/services, process innovations and the role of organisational innovations. This enables us to explore the effect that different innovation types have on the productivity performance for innovators and non-innovators.

The next section presents a review of the literature on the drivers of innovation and the innovation-productivity link. In the following section, the data used in the analysis are outlined, which is followed by a description of the model to be estimated. The results from the empirical analysis are then presented in the penultimate section. A conclusion section concludes the paper.

3.2 | THE INNOVATION PROCESS AND PRODUCTIVITY

Building on the seminal work of Schumpeter (1942) and Porter (1985), amongst others, innovation has received much more attention in recent decades where the link between innovation and economic growth is understood as an endogenous phenomenon (Aghion and Howitt, 1992). Productivity growth through efficiency gains, the creation and satisfaction of new wants, and the innovations driving these changes, are all crucial for firm competitiveness and long term economic growth (Romer, 1990, Baumol, 2002, Bhide, 2011). Despite the importance of innovation in explaining improvements in living standards, efforts to provide appropriate measurements of innovation, models of innovation and a better understanding of the process of innovation have proved to be difficult challenges. Kline and Rosenberg (1986: 275) highlighted the complexity of the innovation process characterizing it as 'complex, uncertain and somewhat disorderly.'

It is useful first to determine what is meant by innovation. For Schumpeter (1934), the entrepreneur is the catalyst of innovation in our society and innovation is the result of entrepreneurial discovery in the market place, which results in new products, new processes, opening of new markets, new ways of organising the business and new sources of supply. The impact of innovation may differ considerably from firm to firm, offering some firms dominant market positions and long term monopoly rents, but also some firms may only achieve very incremental marginal market gains. This is largely due to the variability of innovation types. Gordan and McCann (2005) state that innovations consist of three underlying elements, which include newness (novelty to firm or market), improvement (superiority to what currently exists), and overcoming of uncertainty (improving market share). Our understanding of innovation has also developed significantly over recent decades due to the increased deployment of firm based surveys at national level (Hong *et al*., 2012). Modern firm level surveys have used innovation proxies such as R&D spend and patents activity (Hong *et al*., 2012), but increasingly more discrete dummy variable measures of product or process innovation (Griffith *et al*., 2006, Parisi *et al*., 2006, Van Leeuwen and Klomp, 2006), or innovation sales per employee (Lööf and Heshmati, 2006), and innovation sales share of total sales (Crepon *et al*., 1998, Van Leeuwen and Klomp, 2006) are used. Most modern national and international innovation surveys base their innovation measures on the OECD Oslo Manual (2005). The OECD Oslo Manual (2005) identifies four types of innovation in the firm. These include product, process, marketing and organisational innovations. The focus of our discussion will be on product, process and organisational innovation as the BEEPS data used in this study includes questions in these areas of innovation.

A common distinction is often made in the literature on the differences between product and process innovations. This distinction largely originates from the understanding of the product life-cycle. Utterback and Abernathy (1975) proposed in their model of the 'product-life cycle' that firms compete predominately on product differentiation where research development investment is high to develop product features that they perceive customers to want. Klepper (1996) who surveyed the empirical literature on product life cycles observed that the most recent entrants account for a disproportionate share of product innovations. As the market matures, and the tastes and preferences of consumers become better understood, the focus of firms changes to competing on costs and economies of scale, where process innovation governs the majority of innovation activities of firms. The product life-cycle indicates a complementary relationship between product and process innovations over time. However, the empirical literature has found a complementary relationship between different forms of innovation irrespective of the time dimension as proposed in the product life cycle (Doran, 2012). As Mohnen and Hall (2013) point out, new products may lead to a new production process or technology for production. Therefore, in contrary to the ideas outlined in Utterback and Abernathy (1975), the firm may be forced to consider process innovations when introducing new products. This of course will depend on the degree of complementarity between the production processes of new products and old products. Furthermore, the new product may benefit from the introduction of non-technological process innovations. Mol and Birkinshaw (2009) identify that organisational innovation is often incremental in nature and is distinctly differentiated from product and process innovation and is non-technological. Less research has been completed in the literature on organisational innovation (Lööf and Heshmati, 2006, Raffo *et al*., 2008). We intend studying the effect of the firm's innovation activities on the introduction of innovations in the firm to identify the nature of the relationship between product/service innovations and technological (referred to as process innovations in this paper) and non-technological innovations (referred to as organisational innovations in this paper).

The second relationship we intend to explore is the relationship between firm characteristics and their relationship across innovation types. In terms of internal differences, most studies have taken a resource based view of the firm, where innovation is a result of a process stemming from the firm's core competences (Vega-Jurado *et al*., 2008). The core competencies can be tangible and intangible and are acquired and developed over time (Vega-Jurado *et al*., 2008). The empirical literature has identified the importance of internal resources and capacities for firm innovation. For instance, it is argued that in many industries: in-house R&D (Jaffe, 1986, Crepon *et al*., 1998, Freel, 2003, Roper *et al*., 2008) and investments in machinery and equipment, along with human capital are the driving factors in a firm's innovative performance (Griliches, 1998, Romer, 1990). The firm's stock of knowledge can be embedded within a firm's physical and human capital (Hong *et al*., 2012). Firm size is also identified as an important factor for firms' expenditure on R&D (Shefer and Frenkel, 2005, Crepon *et al*., 1998), with both large firms and small firms found to be highly innovative (Tether, 1998). Pavitt *et al*. (1987) suggested that the relationship between firm size was U-shaped, implying that small firms and large firms have above average innovation intensities, while medium sized firms have below average levels of innovation intensities. Sector and ownership of the business may also affect the likelihood of a firm innovating (Pavitt, 1984) and it is clear from the literature that there are a number of key factors other than R&D that explain the propensity of firms to innovate.

Less has been completed on distinguishing whether the drivers are different across innovation types. Theorectical insights (Audretsch, 1995; Klepper, 1996) into the dynamics and evolution of innovations introduced by entrants and incumbent firms suggest that age and size should be important determinants of whether firms are more likely to product or process innovate. Klepper (1996) predicted the total number of product innovations to decrease over time, new entrants to account for a disproportionate share of product innovations and for larger incumbent firms to focus their attention more towards process innovations. Huergo and Jaumandreu (2004) found that entrants present a high probability of innovating which slowly diminishes over the post-entry life cycle and that exit from the market by firms is associated with a relatively poor pre-exit innovative performance especially in process innovations. We expect age and firm size to have inverse relationships with product and process innovations as predicted by the Klepper (1996) model.

Much of our understanding of innovation has been largely derived from studies focusing on manufacturing firms (Tether, 2005), while services have tended to be seen as being primarily passive adopters of technology and are often referred to as being "users of technology" (Evangelista, 2000, Tether, 2005). However, the evidence from surveys suggests that services do innovate (Tether, 2005). And this follows a shift in thinking around the concept of innovation from a conventional narrow focus on innovation being technological and R&D driven, to a more broadly defined concept, where innovation is also about non-technological innovations and innovation adoption (Hong *et al*., 2012, McCann and Ortega-Argilés, 2013). We expect service firms to be important for introducing and adopting organisational innovations. Organisational innovation has been found also to be important for smaller firms (Gallego and Rubalcaba, 2013).

We further draw on the geographical implications of the product-life-cycle-theory (Vernon, 1966) which is very similar to the regional or urban hierarchy model (Tödtling, 1992, Oakey *et al*., 1988, Roper, 2001). The product life cycle theory argues that there may be a hierarchy urban-periphery effect with innovation and the location of production. The early stage of product/service innovation may occur more often in urban areas that benefit from positive agglomerations. However, when the innovation diffuses, the product/service innovation may start to become standardised where the industry structure starts to shift to a more monopolistically competitive structure and hence, process innovation, scale and cost competitiveness become more important. Therefore, there may be a shift to the periphery of urban regions or rural areas in the later stages of a products 'life' – where costs of production may be lower. The empirical support for the theoretical arguments that underlie the urban hierarchy model are limited (Roper, 2001). In this paper, we attempt to identify whether a higher populated location influences the innovation production potential of manufacturing and service firms across different types of innovation. We further explore whether the aggregate firm effects of R&D spend, capital spend and the level of human capital were influential for innovation intensity at the different types of locations.

We now turn the discussion to the different forms of innovation and their predicted effect on productivity. Following the theoretical literature and the importance attached to innovation for firms it is generally expected that the decision to innovate will have a positive effect on the productivity performance of firms. However, whether this is the case for all firms or for particular types of firms is still empirically rather unclear. While measuring innovation is by no means straightforward, the measurement of firm productivity itself has also varied in terms of the indices adopted by previous studies. Some studies have employed levels measurements for productivity while others have preferred growth rate measurements. Primarily however, level measurements for productivity are used in the literature in order to capture the links between innovation and productivity, and these include the log of value added per worker (Crepon *et al*., 1998, Mairesse and Robin, 2009) or the log of sales per worker (Griffith *et al*., 2006, Jefferson *et al*., 2006, Van Leeuwen and Klomp, 2006), while some studies have also used total factor productivity growth as a measure of productivity (Chudnovsky *et al*., 2006, Lööf and Heshmati, 2006). The use of different innovation indicators as well as different productivity indices therefore makes comparability rather difficult when aiming to identify the empirical links between innovation and productivity.

Product innovation is found to have a positive effect on productivity in many different studies. (such as: Mairesse *et al*., 2005; Parisi *et al*., 2006; Griffith *et al*., 2006; Raffo *et al*., 2008; Mairesse and Robin, 2009; Hall *et al*., 2009) and a negative effect in some other studies (Raffo *et al*., 2008 for Argentinian firms and Duguet, 2006 for incremental innovation)[1]. Process innovation is found to have a positive effect on productivity in many different studies (such as: Huergo and Jaumandreu, 2004; Mairesse *et al*., 2005; Parisi *et al*. ,2006; Griffith *et al*., 2006 for a sample of French firms; Chudnovky *et al*. 2006; Masso and Vahter, 2008) and a negative effect in some studies (Janz *et al*., 2004; Loof and Heshmati, 2006, Van Leeuwen and Klomp, 2006). Roper *et al*. (2008) hypothesised that these negative effects may be due to innovations having a disruptive effect on the firm in the short term, perhaps due to the nature of the product-life cycle and inefficient production at the beginning stages of mass production. Mohnen and Hall (2013) suggest that productivity may decline at the beginning when the product enters the market and over time productivity will improve as the firm moves down the

[1] All of these studies refer to product innovation in manufacturing firms.

learning curve. As such, the time effect may be critical here, with innovation benefits only accruing after certain time-delays, depending on the context. However, Mohnen and Hall (2013) do not expect a similar learning curve with process innovations as new processes are often introduced to reduce production costs. Yet, although the number of studies reporting a negative effect of innovation on productivity is much fewer than those studies reporting a positive effect, the fact that such negative findings do exist (even allowing for publication bias) suggests that there are still important and unresolved issues regarding the links between innovation and productivity which need to be further explored and re-examined.

Similarly, another area which needs to be further examined relates to the issue of non-innovators. The endogenous switching model allows the researcher estimate a counterfactual analysis of the innovation (the treatment) effect on the productivity performance of innovating and non-innovating firms. It further allows the researcher to test whether innovators or non-innovators have an absolute advantage in production because of innovation or because of other heterogeneous factors. Not all innovators necessarily achieve high productivity performance and some non-innovating firms may be very successful. Having a further understanding of these issues may serve to further clarify the nature of the innovation-productivity links. The benefits of this model in helping to undertstand this issue is elaborated upon in the methodology section.

3.3 | DATA

The data employed in this study is from the BEEPS (Business Environment and Enterprise Performance Survey) 2005 survey. The BEEPS 2005 survey was a joint initiative conducted by the World Bank Group (World Bank) and the European Bank for Reconstruction and Development (EBRD). The 2005 survey was the third series of BEEPS to be administered. The principle purpose of the BEEPS data is to assess the business environment for private enterprises in developing countries. The 2005 series was conducted in 28 different countries and approximately 9,500 firms participated. From the 2005 series, five reference countries from the EU were chosen which included Portugal, Greece, Germany, Spain and Ireland.

In each country sampling frames were constructed from National statistical institutes, Chamber of Commerce membership lists, industry registers and commercial sources such as the Yellow Pages (Synovate, 2005). For some enterprise parameters (such as the distribution of firms per county/region) statistical information such as population density and employment levels were also employed to identify an appropriate sampling frame (Synovate, 2005). The sampling design was as representative as possible (and therefore, self-weighted) in terms of industry sector and contribution to GDP levels, firm size and location.

The target firm population comprised enterprises that were established prior to 2002, and had between 2 and 10,000 employees. In each country, the sectoral composition of the sample in terms of manufacturing and service industries were to be determined by their relative contribution to GDP. Firms that operate in sectors subject to government intervention in terms of price regulation and prudential supervision, such as banking, electric power, rail transport, and water and waste water, were to be excluded from the sampling frame. The survey methodology was to be broadly representative of the market-driven sectors of each country consisting of the relative mix of manufacturing and services enterprises and stratified random sampling classified principally by industry, establishment size and region (Synovate, 2005).[2]

A total of 501 firms completed the BEEPS survey in Ireland and our econometric analysis was conducted on 436 firms when missing observations for some variables were accounted for. A detailed list of the variables to be employed in this study is outlined in Table 3.1. An extensive set of explanatory factors are employed in the models that include variables on firm performance, firm characteristics, public support, location and market environment variables.

Table 3.1 | Variable Descriptions

Dependent variables – innovation and performance indicators	
Product or service	=1 if firm 'developed successfully a major new product line or service over the last 36 months, and/or if the firm 'upgraded an existing product line or service' over the last 36 months', 0 otherwise.
Process innovation	=1 if firm has 'acquired new production technology over the last 36 months', 0 otherwise.
Organisational innovation	= 1 if firm has had 'a completely new organisational structure' or 'had a major reallocation of responsibility and resources between departments' over the last 36 months, 0 otherwise.
Research and development	=1 if the firm had positive spending on R&D including wages and salaries of R&D personnel, R&D materials, R&D education and R&D related training, 0 otherwise.
Turnover per worker	Firms total sales in 2004 divided by the number of full-time employees in the business in 2003.
Independent variables	
Firm Characteristics	
Age of firm in 2005	Years since firm first began operations in this country.
Log of Employment (2003)	Log of the number of full-time employees in the business three years ago (2003).
Small firm	=1 if the firm has 2-49 employees, 0 otherwise.
Medium firm	=1 of the firm has 50-249 employees, 0 otherwise.
Large firm	=1 if the firm has 250-9,999 employees, 0 otherwise.

[2] The BEEP's series have been principally employed to examine aspects of the business environment in developing countries and to examine the impact of criminal activity and corruption on business development in developing countries. In terms of innovation studies, Roper (2009) has a working paper examining innovation policy in the Balkan countries. Aghion *et al*. (2002) examined competition, innovation and economic growth in transition countries. Seker (2012) conducted a study on importing, exporting and innovation in developing countries. A detailed analysis of the data collection method may be obtained in Synovate (2005)

Table 3.1 | Variable Descriptions *(Continued)*

Capital intensity	Positive spending on new buildings, machinery and equipment divided by the number of full time employees in 2003.
Professional Category (%)	What percentage of the workforce are professionals (i.e. scientists, engineers and accountants)?
Domestic	=1 if majority of firm is Irish owned (greater than 50 per cent), 0 otherwise.
Exporting firm	=1 if the firm currently sell its products or services directly to customers outside the country, 0 otherwise.
Multi-plant firm	=1 if the firm has many establishments (separate operating facilities) in this country, 0 otherwise. *Innovations in other subsidiaries are not taken into recorded.
Location and Markets	
Capital	=1 if firm is located in the Dublin city area, 0 otherwise.
City pop 50k-250k	=1 if firm is located in an urban area with a population between 50k-250k, 0 otherwise.
City pop less than 50k	=1 if firm is located in a village or town with a population of less than 50k, 0 otherwise.
Construction and Mining	=1 if firm is in ISIC Section C (10-14), Section F (45), 0 otherwise.
Manufacturing	=1 if firm is in ISIC Section D (15-37), 0 otherwise.
Services	=1if firm is in ISIC Section I (60-64); Section G (50-52); Section K (70-74); H(55) 0 (which includes motion picture and video activities, other entertainment activities, news agency activities and other service activities), 0 otherwise.
Pressure from domestic	
competitors	=1 if pressure from domestic competitors was fairly important or very important for product/service or process innovation, 0 otherwise.
Pressure from foreign	
competitors	=1 if pressure from foreign competitors was fairly important or very important for product/service or process innovation, 0 otherwise.
Pressure from customers	=1 if pressure from customers was fairly important or very important for product/ service or process innovation, 0 otherwise.
Public Support	
Subsidies from state	=1 if the firm over the last 36 months has received any subsidies from the national government, 0 otherwise.
Subsidies from region	=1 if the firm over the last 36 months has received any subsidies from the regional/ local government, 0 otherwise.
Subsidies from EU	=1 if the firm over the last 36 months had received any subsidies from EU sources, 0 otherwise.

Source: Business Enterprise Survey for Ireland 2005.

Table 3.2 | Descriptive Statistics of Firm Data

Dependent Variables	**Mean**	**Standard Deviation**
Product or service (%)	61.0	48.8
Process innovation (%)	38.7	48.7
Organisational innovation (%)	44.0	49.7
Log of turnover per worker	11.8	1.1
Research and development	23.4	42.4
Independent Variables		
Firm Characteristics		
Age of firm in 2005 (level)	22.7	22.9
Log of employment (2003) (level)	2.5	1.6
Small firm (%)	78.2	41.3
Medium firm (%)	15.1	35.8
Large firm (%)	6.7	24.9
Professional Category (%)	8.13	18.1
Domestic (%)	89.7	30.5
Exporting firm (%)	31.6	46.5
Multiplant firm (%)	22.9	42.1
Location and Markets		
Capital (%)	33.3	47.1
City pop 50k-250k (%)	17.4	37.9
City pop under 50k (%)	49.3	50.0
Pressure from domestic competitors (P/S) (%)	67.6	46.8
Pressure from foreign competitors (P/S) (%)	35.5	47.9
Pressure from customers (P/S) (%)	78.8	40.8
Pressure from domestic competitors (P) (%)	69.7	46.0
Pressure from foreign competitors (P) (%)	36.7	48.3
Pressure from customers (P) (%)	86.0	34.7
Construction and mining (%)	10.4	30.5
Manufacturing (%)	34.6	47.6
Services (%)	55.0	49.8
Public Support		
Subsidies from state (%)	4.3	20.4
Subsidies from region (%)	3.9	19.4
Subsidies from EU (%)	2.8	16.4

Source: Authors own calculations using BEEPS (2005) data.

Notes:

1. P/S represent new and upgraded products and services
2. P represent new processes

In terms of our response variables, three types of innovation outcomes are analysed in this study, namely: (i) new products/services and the upgrading of existing products/services[3] (ii) the introduction of a new production technology, and (iii) a 'completely new organisational structure' or 'had a major reallocation of responsibility and resources between departments'. The innovations had to have taken place in the previous 36 months of the year the survey was completed. In comparison to CIS studies, the only drawback of the BEEPS innovation indicators is that it is unknown whether the innovations were new to the firm or new to the market. In terms of our explanatory variables, as we see in Tables 3.1 and 3.2, the firm performance indicators include productivity (measured as the log of turnover per worker), and a range of variables describing the characteristics of each firm including, the level of human capital (measured by the percentage of the workforce in the professional category), the type of firm ownership, the age of the firm, and the size of the firm. The variables of city size, pressure from customers, pressure from domestic and foreign competitors, as well as support from EU, national and regional institutions, are all used as indicators of the operating market environment of Irish firms.

3.4 | METHODS

In this paper an endogenous switching model is employed within a production function framework. The model has been used to examine questions in many different areas; Lee (1978) on union membership and wage rates; Adamchik and Bedi (2000) to assess wage differentials of workers in the public and private sectors in Poland; and the innovation impact of IT outsourcing on firm success (Ohnemus, 2007).

The conceptual difference between the use of an endogenous switching model and Heckman's (1979) selection model is based on the researcher's objectives (Dutoit, 2007). Dutoit (2007) outlines that the switching model should be used when the relationship between a variable of interest and a set of explanatory variables varies across discrete regimes. In Heckman's (1979) selection model, the researcher starts from one observed regime only and intends to explain this relationship only (Dutoit, 2007). It is assumed in this paper that the desire for the firm to achieve a high productivity performance will influence the decision of the firm to innovate or not to innovate – hence the introduction of a new innovation is endogenous to the future productivity performance of the firm. Given that selection into the observed regime is endogenous, the alternative regime (unobserved) must be taken into account, with the estimation auxiliary equation (Dutoit, 2007). The use of switching models allows the researcher to identify both regimes from the beginning and conclusions can be drawn from both regimes (Dutoit, 2007). By following the switching model approach using innovation and productivity outcomes, we are specifically interested in drawing conclusions on

[3] On the theoretical grounds outlined in the literature section between the differences between product and process innovation we argue that the innovation process for new products and services and upgraded products and services is likely to be similar (firms try to differentiate their product/service from other products and services in the market place) and hence we have combined these measures. The correlation between the measures for new and improved products and services is 42 per cent.

what type of firms are more likely to innovate and on the performance of firms that innovate versus firms that do not innovate.

Therefore, following Lokshin and Sajaia (2004), the endogenous switching model specification takes the following form:

$$I_i = 1 \; if \; yZ_i + yW_{ij}^{*} + u_i > 0 \tag{1}$$
$$I_i = 0 \; if \; yZ_i + yW_{ij}^{*} + u_i \leq 0 \tag{2}$$
$$Regime\ 1{:}\ Y_{1i} = \beta_1 X_{1i} + yW_{ij}^{*} + e_{1i} \quad if\, I_i = 1 \tag{3}$$
$$Regime\ 2{:}\ Y_{2i} = \beta_2 X_{2i} + yW_{ij}^{*} + e_{2i} \quad if\, I_i = 0 \tag{4}$$

Where, Y_{1i} is the natural log of productivity per worker for innovating firms in regime one and Y_{2i} is the natural log of productivity per worker of non-innovating firms in regime two; I_i is a latent variable for the decision to innovate; X_{1i} and X_{2i} are vectors of independent variables for regimes one and two[4]. The chosen variables X_{1i} and X_{2i} are proxy indicators for the log of capital intensity per worker, the log of full time employees in the firm, the age of the firm, a domestic firm dummy, whether the firm is a multi-plant firm, industry sector dummies and location dummies. Z_i is a vector of firm characteristics and locational indictors regarding the decision to innovate. In addition to the variables included in X_{1i} and X_{2i}, Z_i includes public support dummies, percentage of the workforce in the professional category and market environment dummies; β_1, β_2 and y are vectors of parameters; e_{1i}, e_{2i} and u_i are the random disturbance terms. We run the endogenous switching model for the three different I_i treatment effects (product, process and organisational innovation) separately.

We now turn our attention to W_i^{*} which depicts an innovation effort instrument estimated using observed innovation behaviour depicted by W_{ij} (in equation 5). We take innovation efforts to be the effects of 'what else' the firm is doing in the area of innovation activities within the firm. In our data we have innovating firms that have: (1) introduced product innovations and may be doing other innovation efforts[5]; (2) introduced process innovations and may be doing other innovation efforts[6]; (3) introduced organisational innovations and may be doing other innovation efforts[7]. The innovation effort instrument employed in our model solves for endogeneity issues, which may arise between different innovation indicators in the model depicted in equation (1). We identify two potential endogeneity issues in our initial model. The first endogeneity issue that may arise is the relationship between the dependent variable I_i and W_{ij}. To solve for this problem, we build upon an approach taken by Griffith *et al*. (2006). Griffith *et al*. (2006) used the predicted values estimated from reported R&D figures to proxy for innovation effort. The difference in our approach is that in

[4] In order to account with issues of specification and degrees of freedom there are less independent variables specified in the regime equations to those in the selection equation.

[5] In this case, other innovation efforts by the firm may be spending on R&D and/or introducing a process innovation and/or introducing an organisational innovation.

[6] In this case, other innovation efforts by the firm may be spending on R&D and/or introducing a product innovation and/or introducing an organisational innovation.

[7] In this case, other innovation efforts by the firm may be spending on R&D and/or introducing a product innovation and/or introducing a process innovation.

addition to using R&D activities, we also include other reported innovation efforts such as other innovation outputs introduced by the firm in the survey period. Hence, we are using more than one proxy variable for innovation effort to that of the estimation employed by Griffith *et al*. (2006).

A second endogeneity issue that may arise is between the observed proxy variables for innovation effort depicted by W_{ij}. Gordon and McCann (2005) argue that making a distinction between product and process innovations is difficult as new processes can allow new products to be developed, and mass production of successful new products may require process innovation. Further, the empirical literature has found a complementary relationship between different forms of innovation (Doran, 2012). Hence, we explore by means of a multivariate probit model (Greene, 2003) whether our innovation effort proxies (W_{ij}) are related or unrelated (Greene, 2003). In this paper, the multivariate probit model includes three equations estimating the effect of other innovation efforts. Considering we have three types of innovating firms as outlined earlier − three innovation effort instruments are estimated for firms that have introduced a product innovation or not, firms that introduced a process innovation or not and firms that have introduced an organisational innovation or not. These multivariate probit models to be estimated may be depicted as:

$$\begin{gathered} W^*_{ij} = \alpha_j + \beta'_j Z_{ij} + u_{ij}, \quad where \\ W_{ij} = 1 \text{ if } W^*_{ij} > 0, \text{ and } 0 \text{ otherwise} \\ i = 1, ..., n \\ j = 1, ..., 3 \\ E[ui1] = E[ui2] = E[ui3], \\ Var[ui1] = Var[ui2] = Var[ui3] = 1 \\ Cov[ui1, ui2, ui3] = p \end{gathered} \tag{5}$$

Where the observations are indexed by *i* and the innovations by *j*. The multivariate probit model is a natural extension of the bivariate and probit model, which allows for more than one equation with correlated disturbances (Galia and Legros, 2004). This method allows for the disturbances to be freely correlated. It's through examining $p_i = 0$ that enables the researcher to identify if the correlation between the equations is statistically significant and whether the unobserved effects in each model are correlated or not. To enable progression through the model employed in this paper we will assume that W_{ij} are related and endogenous to one-another. Hence, our innovation effort proxy W^*_{ij} is inserted into our original endogenous switching model in equations (1-4). Z_i in equation (5) is restricted to firm size dummies (small, medium and large firms), sector type and whether the firm exports or not.

Following this, we now return to discuss our original endogenous switching model in equation (1-4). If firms select to innovate or not to innovate based on unobservable factors a selection bias problem may occur in the endogenous switching model. If such a scenario occurs, then a nonzero covariance exists between the determination of innovation and productivity. The benefit of the switching model is that all equations (1) to (4) can be estimated at the same time with simultaneous maximum likelihood estimation which controls for such potential selection bias (Dutoit, 2007; Lokshin and Sajaia, 2004). Following Lokshin and Sajaia (2004: 283), e_{1i}, e_{2i} and u_i are assumed to have a trivariate normal distribution with mean vector zero and covariance matrix:

$$\Omega = \begin{bmatrix} \sigma_u^2 & \sigma_{1u} & \sigma_{2u} \\ \sigma_{1u} & \sigma_1^2 & \cdot \\ \sigma_{2u} & \cdot & \sigma_2^2 \end{bmatrix}$$

where σ_u^2 is the variance of the error term in the selection equation and can be assumed to be equal to 1 as *y* can only be estimable up to a scalar factor (Maddala, 1983: 223). σ_1^2 and σ_2^2 are the variances of the error terms in the productivity equations. σ_{1u} and σ_{2u} represent the covariance of u_i and e_{1i} and u_i and e_{2i}, respectively. Y_{1i} and Y_{2i} are not observed simultaneously so the covariance between e_{1i} and e_{2i} is not obtained (represented by the dots in the matrix Ω, see Maddala, 1983: 224 and Lokshin and Sajaia, 2004:283). Full information maximum likelihood is employed to estimate the endogenous switching models. Given the assumptions outlined previously on the distribution of the error terms and following Lokshin and Sajaia (2004:283) the log likelihood function can be defined as:

$$InL = \sum_{i\text{-}1} \{I_l o_i [\ln(F(\eta_{1i})) + \ln \left(\frac{f\left(\frac{e_{1i}}{\sigma_1}\right)}{\sigma_1} \right)] + (1 - I_i) o_i \left[\ln(1 - F(\eta_{2i})) + In \quad \left(f\left(\frac{e_{2i}}{\sigma_2}\right) / \sigma_2 \right)\right]\}$$

Where *F* is a cumulative density function, *ƒ* is a normal density function, o_i is an optional weight for observation *i* and

$$\eta_{ji} = \frac{(yZ_i + \rho_j e_{ji}/\sigma_j)}{\sqrt{1 - \rho_j^2}} \, j = 1,2$$

Where $p_1 = \sigma_{1u}^2/\sigma_u \sigma_1$ denotes the correlation coefficient between the error term u_i of the selection equation and the error term e_{1i} of the first regime equation and $p_2 = \sigma_{2u}^2/\sigma_u \sigma_2$ denotes the correlation coefficient between the error term u_i of the selection equation and the error term e_{2i}. The value of ρ_1 and ρ_2 are of particular interest in the analysis. If $\rho_1 = \rho_2 = 0$, then the relationship is exogenous and if ρ_1 and $\rho_2 \neq 0$, then endogeneity arises, and the implication is that unobservable characteristics are important in explaining both the selection equation and also the outcome equation and that the hypothesis of no selection bias can be rejected (Di Falco *et al*., 2011).

We can also investigate the firms' relative performance from innovating or not innovating. This comparison can be presented by calculating the conditional expectation outcomes after running the endogenous switching model. Again we follow Lokshin and Sajaia, (2004) and after the parameters are estimated (equation 1-4), we can calculate:

$$E(Y_{1i}|I_i = 1, x_{1i}) = x_{1i}\, \beta_1 + \sigma_1\, \rho_1\, f(\gamma Z_i)/F(\gamma Z_i) \tag{6}$$

$$E(Y_{2i}|I_i = 0, x_{2i}) = x_{2i}\,\beta_2 + \sigma_2\,\rho_2\, f(\gamma Z_i)/F(\gamma Z_i) \tag{7}$$
$$E(Y_{2i}|I_i = 1, x_{1i}) = x_{1i}\,\beta_1 - \sigma_1\,\rho_1\, f(\gamma Z_i)/(1 - F(\gamma Z_i)) \tag{8}$$
$$E(Y_{1i}|I_i = 0, x_{2i}) = x_{2i}\,\beta_2 - \sigma_2\,\rho_2\, f(\gamma Z_i)/(1 - F(\gamma Z_i)) \tag{9}$$

$E(Y_{1i}|I_i = 1, x_{1i})$ represents the conditional expectation of innovating firms' performance from innovating; $E(Y_{2i}|I_i = 1, x_{1i})$ represents the conditional expectation of innovating firms' performance without innovating; and $E(Y_{1i}|I_i = 0, x_{2i})$ represents the conditional expectation of non-innovating firms' performance if they innovated; $E(Y_{2i}|I_i = 0, x_{2i})$ represents the conditional expectation of non-innovating firms' performance if they did not innovate.

Table 3.3 | Average Expected Log of Productivity per Worker per Firm for Innovators and Non-Innovators

Sub-Samples	**Innovator**	**Non-innovator**	**Treatment Effect**
Firms that innovated	(A) $E(Y_{1i}\|I_i = 1, x_{1i})$	(C) $E(Y_{2i}\|I_i = 1, x_{1i})$	TT
Firms that did not innovate	(D) $E(Y_{1i}\|I_i = 0, x_{2i})$	(B) $E(Y_{2i}\|I_i = 0, x_{2i})$	TU
Heterogeneity	BH^1	BH^2	TH

Notes:

1. A and B represent observed expected log of productivity per worker; C and D represent counterfactual expected log of productivity per worker.
2. *Ii* =1 if firms innovated; *Ii* = 0 if firms did not innovate;
3. Y_{1i} and Y_{2i} are the log of productivity per worker of firms;
4. TT: the effect of the treatment (i.e., innovators) on the treat ed (i.e., firms that innovated);
5. TU: the effect of the treatment (i.e., innovators) on the untreated (i.e., firms that did not innovate);
6. BHi : the effect of base heterogeneity for firms that innovated (i =1), and did not innovate (i = 0);
8. TH = (TT – TU), i.e., transitional heterogeneity

In line with Di Falco *et al*. (2011), the conditional expectations outlined above can be used to compare the observed outcomes and the counterfactual cases. While Di Falco *et al*. (2011) applied the analysis to farming and climate change, we apply the approach using the expected productivity per workers of firms that innovated, with respect to the firms that did not innovate, and also to examine the expected productivity of firms in the counterfactual hypothetical cases. The conditional expectations of the four cases are presented in Table 3.3. Cases (6) and (7) represent the actual expectations observed in the sample. Cases (8) and (9) represent the counterfactual hypothetical expected outcomes.

$$TT = E(Y_{1i}|I_i = 1, x_{1i}) - E\,(Y_{2i}|I_i = 1, x_{1i}) \tag{10}$$
$$TU = E(Y_{1i}|I_i = 0, x_{2i}) - (Y_{2i}|I_i = 0, x_{2i}) \tag{11}$$
$$BH^1 = E(Y_{1i}|I_i = 1, x_{1i}) - E(Y_{1i}|I_i = 0, x_{2i}) \tag{12}$$
$$BH^2 = E(Y_{2i}|I_i = 1, x_{1i}) - E(Y_{2i}|I_i = 0, x_{2i}) \tag{13}$$
$$TH = TT - TU \tag{14}$$

Using (6) and (8), we can estimate a sampled innovating firms' expected productivity from innovating minus the firms' expected performance from not innovating. TT measures the sampled innovating firms' mean productivity gain (or loss) from innovation. In other words it can be described as calculating the effect of treatment to innovate on the treated. Using (7) and (9), we can estimate the sampled non-innovating firms' expected productivity gain (loss) from not innovating. TU measures the mean productivity gain (or loss) for the sampled non-innovating firms' that innovated. In other words it can be described as calculating the treatment to innovate on the untreated for the firms that did not innovate. We can use the conditional expected outcomes to examine the heterogeneity effects: firms that innovated may have higher productivity per worker levels regardless of whether they innovated or not, due to unobservable characteristics. BH^1 represents the base heterogeneity for the firms that innovate. BH^2 represents the base heterogeneity for the firms that do not innovate. TH examines whether the effect of innovating is larger or smaller for firms that actually innovated or for firms that did not innovate in the counterfactual case that did innovate, represented in the difference between TT and TU. The t-test method is employed to calculate the significance levels for equations (10) – (14).

3.5 | RESULTS

The models for the endogenous switching model are significant across all innovation types. In this section, we firstly analyse the factors that have a positive (or negative) and significant effect on the likelihood of firms introducing new products and services, process innovations and organisational innovations. We take particular interest in the differences between the effects of internal factors and location of the firm across innovation types. In the second section our focus is on the effects of innovation on the productivity performance of both innovating and non-innovating firms. In that section we examine whether the decision to innovate had a positive or negative impact on the firm's level of productivity and if the productivity levels would have been higher if the firm had taken the alternative strategy (the counterfactual)[8].

The Innovation Selection Equation

This section examines the production of knowledge into different types of innovations represented by the first step of the endogenous switching model using an innovation production function approach as outlined in the methodology section. The results from this step of the analysis are presented in Table 3.4.

[8] We decided not to include the results from the innovation effort models and the factors affecting productivity levels (other than the effect of innovation) in the main results section as we are specifically interested on the drivers of product, process and organisational innovations and their effects and counterfactual effects on the productivity of innovating and non-innovating firms in this study. The estimations for the innovation effort step indicate that the processes explaining R&D activity, process innovations, and organisational innovations are dependent. Hence, we use predicted values for innovation effort in the selection equation of the endogenous switching model. Furthermore, the innovation effort of firms is not found to have a significant effect on the productivity levels of innovating or non-innovating firms. Results from these steps are available from the authors on request.

Table 3.4 | Endogenous Switching Model – Innovation Selection Estimation

Independent Variables	Prod/Ser	Process	Organisational
Firm Characteristics			
Innovation effort	1.1134***	0.1938	-0.2502
	(0.2867)	(0.2549)	(0.3123)
Log of employment (2003)	-0.0989	0.1042*	0.1678**
	(0.0659)	(0.0617)	(0.0691)
Log of Capital per worker	0.0290*	0.0403***	0.0415**
	(0.0165)	(0.0120)	(0.0179)
Professional (%)	0.0089**	0.0014	0.0043
	(0.0039)	(0.0026)	(0.0036)
Age of the firm	-0.0000	-0.0019	-0.0071**
	(0.0029)	(0.0028)	(0.0033)
Domestic	0.3619	0.3912	0.4268*
	(0.2660)	(0.2664)	(0.2590)
Part of multi-plant	0.1173	0.0218	0.4760***
	(0.1774)	(0.1730)	(0.1727)
Location and Markets			
City pop 50k-250k	-0.3770*	0.0381	-0.9967***
	(0.2042)	(0.1932)	(0.2198)
City pop under 50k	-0.3746**	0.2545**	-0.3773***
	(0.1554)	(0.1457)	(0.1544)
Pressure from domestic			
Competitors	0.2323	-0.0838	-0.1353
	(0.1504)	(0.1290)	(0.1618)
Pressure from foreign			
Competitors	0.3676**	0.1777	0.4516*
	(0.1581)	(0.1179)	(0.1545)
Pressure from customers	0.0393	0.3442**	0.3346*
	(0.1976)	(0.1562)	(0.1985)
Construction and mining	-0.6301***	-0.5193**	0.0884
	(0.2492)	(0.2527)	(0.3143)
Services	-0.4136***	-0.4796***	-0.0668
	(0.1558)	(0.1402)	(0.2257)
Public Support			
Subsidies from state	0.0744	0.4560*	1.259***
	(0.4122)	(0.3081)	(0.4748)
Subsidies from region	0.6978*	0.3712	-0.1106
	(0.3941)	(0.2841)	(0.3427)

3

Table 3.4 | Endogenous Switching Model – Innovation Selection Estimation *(Continued)*

Subsidies from EU	0.8660	0.0629	0.4986
	(0.6299)	(0.3103)	(0.5168)
No of Observations	*436*	*436*	*436*
Wald Chi^2	36.98	25.00	19.10
	(0.000)	(0.003)	(0.024)
Log Likelihood	-902.58	-885.08	-900.99

Notes:

1. Variables with *** are significant at 1% level, ** are significant at 5% level and * are significant at 10% level. Only significant variables are reported.
2. Standard error are in parentheses.
3. Manufacturing and capital city are the reference categories.

The innovation effort indicator is found to be positive and significant for firms introducing product/service innovations. Surprisingly, innovation effort is not significant for firms introducing process and organisational innovations. This suggests that the likelihood of a firm introducing product/service innovations is dependent on other forms of innovation efforts such as investment in research and development and/or process and/or organisational innovations. However, process and organisational innovations do not require similar investment in innovation efforts by the firm for them to be introduced. We find that firm size is positively related to the likelihood of introducing process or organisational innovations, and on this point, Roper (2001), Jordan and O'Leary (2008) and Roper *et al*. (2008) all found similar results for process innovation in Irish manufacturing firms. In light of the discussion previously on the product life cycle, this result is not surprising. However, what is surprising is that age is not significant across innovation types apart from older firms being less likely to introduce organisational innovations. The firm's capital intensity per worker is also found to have a positive effect on the likelihood of introducing all forms of innovation types. Human capital, in terms of the proportion of workers in the professional category, is found to have a significant effect on the probability of introducing product/service innovations. Roper (2001) found that firms with a higher proportion of graduates are more likely to introduce new and improved products in Irish firms. Roper *et al*. (2008) found a weak relationship between staff education and product and process innovation. Domestic firms are more likely to introduce organisational innovations. Finally, in terms of firm characteristics, firms that are a part of a multi firm organisation are more likely to introduce new organisational innovations, presumably reflecting the on-going coordination challenges faced by such organisations.

In terms of sectors, the picture is very clear. Firms in the construction and mining, and service categories are significantly less likely relative to manufacturing firms to introduce product/service and process innovations. Much of our understanding of innovation has been largely derived from studies focusing on manufacturing firms (Tether, 2005), while services have tended to be seen as in the main as being primarily passive adopters of technology and are often referred to as being "users of technology" (Evangelista, 2000, Tether, 2005). It is evident here from this study that firms in the service industry do indeed innovate, but are less likely to innovate relative to manufacturing firms in product/service innovation and process innovation.

With regard to the external environment, pressure from foreign competitors increases the likelihood of introducing new product/service innovations and organisational innovations, and pressure from customers increases the likelihood of introducing process innovations and organisational innovations. This former finding may be due to the need to stay both competitive in satisfying customer tastes and preferences, whilst remaining price competitive in the market, whereas the latter result may be solely influenced by the demand from customers for lower prices. Meanwhile, subsidies from national sources are also found to have a significant and positive effect for firms that introduce process and organisational innovations, whilst subsidies from regional sources is found to be significant for product/service innovations. However, it is important to note that the interpretation of these coefficients may be complicated by the possibility of sample selection (Maddala, 1983; Roper, 2001). If assistance is given to firms that are more likely to innovate than the average firm, then this finding might be affected by the fact that these types of firms have a greater propensity to innovate with or without grant aid anyway. If assistance was given to firms that were less likely to innovate than the average firm (prior to 2002) then this result suggests that assistance is having a positive effect in improving the likelihood of firms innovating.

Where our results differ significantly from previous Irish innovation studies is with respect to the role of economic geography in innovation. Our results suggest that location is indeed important in terms of various types of innovations being introduced. Firms located in cities of 50,000-250,000 people and firms located in towns of under 50,000 people are statistically less likely to introduce product/service innovations and organisational innovations. Our findings therefore do lend some support to urban hierarchy arguments, in the sense that certain types of innovations are more likely to be undertaken or introduced in more urbanised locations. As such, our geography-innovation findings do go somewhat against the earlier findings that there is little or no economic geography effect in Ireland, as previously reported; found in Roper (2001) and Frenkel *et al*. (2003). Indeed, Jordan and O'Leary (2008) is the only previous study in the Irish case to find something of an urban effect, where high-tech business located in more urban areas were found to be more likely to be product innovators than businesses in less densely populated or rural areas. However, in that same study, the Greater Dublin Area dummy variable was also found to be insignificant, a finding which is at odds with the findings in this paper. Our results are in part consistent with the urban hierarchy model, as product/service innovations are more likely to occur in greater populated areas and technological process innovations are more likely to happen in firms located in towns with a population of 50,000 or less. We also explored the effect of inter-firm regional differences with R&D spend, human capital and capital spend on the propensity of firms to innovate. We identified no regional differences with respect to these indicators[9]. Hence, it is likely that it is external factors to the firm that are significant

[9] These variables were excluded from the final regression estimates. The result estimations that include interaction variables measuring the regional and inter-firm characteristics are available from the authors on request.

in explaining the location differentials of different types of innovative firms. Although, identifying what external factors are important is difficult in this case as we can only decipher that urban effects are more important for the propensity of firms to innovate in products/services and organisational innovations, but urban effects are less important for process innovations. The exact underlying drivers of these urban effects are unclear.

The Relationship between Innovation and Productivity for innovating and non-innovating firms

As alluded to earlier, the use of the endogenous switching model is important to identify whether the firm's decision to innovate and the labour productivity of firms are correlated and if there is a two-way causation effect between innovation and productivity. Interestingly, we find an endogenous relationship between process innovation and productivity and an exogenous relationship between product/service and organisational innovation and productivity[10].

Table 3.5 | Average Expected Log of Productivity per Worker per Firm for Product/Service Innovators and Non-Innovators

Sub-Samples	Innovator	Non-innovator	Treatment Effect
Firms that innovated	(A) 11.799	(C) 11.861	TT = -0.061**
Firms that did not innovate	(D) 12.133	(B) 11.739	TU = 0.393***
Heterogeneity	BH^1 = -0.333***	BH^2 = 0.122***	TH = -0.454***

Notes: Variables with *** are significant at 1% level, ** are significant at 5% level and * are significant at 10% level.

Table 3.6 | Average Expected Log of Productivity per Worker per Firm for Process Innovators and Non-Innovators

Sub-Samples	Innovator	Non-innovator	Treatment Effect
Firms that innovated	(A) 11.661	(C) 9.777	TT = 1.859***
Firms that did not innovate	(D) 12.680	(B) 11.908	TU = 0.772***
Heterogeneity	BH^1 = -1.049***	BH^2 = -2.136***	TH = 1.087***

Notes: Variables with *** are significant at 1% level, ** are significant at 5% level and * are significant at 10% level.

[10] A likelihood ratio (LR) test of independent equations is inherently estimated with the Movestay command in Stata. The LR test indicates that we can reject the null hypothesis (at the 1 per cent level) that the equations measuring process innovation and productivity are independent and we cannot reject the null hypothesis (prob > chi^2 = 0.000) that the equations measuring product/service innovation and productivity and organisational innovation and productivity are independent (prob > chi^2 = 0.340 and prob > chi^2 = 0.7752 respectively).

Table 3.7 | Average Expected Log of Productivity per Worker per Firm for Organisational Innovators and Non-Innovators

Sub-Samples	Innovator	Non-innovator	Treatment Effect
Firms that innovated	(A) 11.819	(C) 11.896	TT =- 0.078**
Firms that did not innovate	(D) 12.149	(B) 11.742	TU = 0.406**
Heterogeneity	BH^1 = -0.329***	BH^2 = 0.154***	TH = -0.484***

Notes: Variables with *** are significant at 1% level, ** are significant at 5% level and * are significant at 10% level.

Tables 3.5-3.7 provide an examination of the treatment and heterogeneity effects for all types of innovations. The treatment effect of innovation on the productivity levels of innovating firms are mixed across innovation types. We find product innovation and organisational innovation have a negative effect on the productivity levels of innovating firms, whilst process innovation has a *strong* positive effect on the productivity levels of innovating firms. These findings support the theoretical proposition by Mohnen and Hall (2013), who suggest that productivity may decline for a period of time after the introduction of a new product innovation, but process innovation should have a positive effect as they are often introduced to reduce production costs. In light of this, the finding for organisational innovation is a bit of an anomaly as these types of innovations would be more akin to the effects of process innovation in reducing production costs than to product innovations. Interestingly, the counterfactual results on the treatment effect of innovation for non-innovating firms are for the most part different to that of innovating firms. All types of innovations are found to have a positive effect on the productivity levels of non-innovating firms. The results further indicate that there are some important sources of heterogeneity that make non-process innovating firms more productive than process innovating firms. This suggests that non-process innovating firms possess an absolute advantage in production. However, if non-innovating firms would benefit from innovation why don't they innovate? The answer to this question could be very complex, but central to any reason is the uncertainty inherent in any innovation. For instance, the non-innovator may not have identified an appropriate innovation to introduce over the survey period and hence we cannot assume that the firm did not want to innovate. Further, investment in innovations is expensive and the firm may not have the resources to invest or the appetite to risk investment in innovations (Rosenburg, 2004) at that particular period in time. Hence, it is even more imperative to ensure that the barriers to innovation for non-innovating firms are identified so that any bottlenecks inhibiting firms to innovate may be helped by policy intervention.

3.6 | CONCLUSIONS

This paper attempts to provide a better understanding of the systemic relationship between innovation and productivity of Irish firms. The study uses an endogenous switching model, which allows the researcher to examine a number of different aspects of the innovation and productivity

3

performance of firms whilst controlling for endogeneity and selection bias. Firstly, the factors that are important for enhancing (or inhibiting) the propensity of a firm to innovate were analysed and secondly, the productive returns from different types of innovation for firms were then examined.

Some of the findings reinforce the traditional patterns in the innovation literature. We do find innovation effort, human capital, firm size and the capital intensity of firms to matter. However, the importance of these factors differs for each type of innovation. Innovation effort and human capital are important for product innovations, but are not significant for process and organisation innovations and firm size matters for process and organisation innovations only. Our results do support the urban-hierarchy model where 'urbanisation' is very important for product innovation and less important for process innovations. This finding is important mainly for two key reasons. Firstly, there has been little evidence of an urban or location effect found in the Irish case in previous innovation studies. Secondly, the findings indicate a potential regional winners and losers scenario on the Island. In terms of product innovation and organisational innovations the losers seem to be towns and villages where the population is less than 50,000 and cities where the population is between 50,000 and 250,000. The key winner in terms of these innovations is Dublin (the capital city). However for process innovation almost the reverse is the case where firms located in towns and villages with less than 50,000 are more likely to process innovate, relative to the capital city. However, a limitation behind the locational measures employed in this survey is that they provide little insight into the actual underlying drivers of the locational differences that are emerging in our analysis. Hence, it is imperative that future data sources allow for an improved exploration of the what these underlying drivers may be.

Product/service and organisational innovation are found to have a negative effect on the productivity performance of firms and process innovation is found to have a positive effect on the productivity performance of firms. This finding is not surprising given similar findings in the literature where product innovation was identified (Roper *et al*. 2008; Raffo *et al*., 2008 and Duguet, 2006) to have a disruptive effect and process innovation is identified as having a positive effect on the productivity performance of firms (Huergo and Jaumandreu, 2004; Mairesse *et al*., 2005; Parisi *et al*., 2006). The theoretical literature also outlines that time delays in terms of translating innovations into productivity gains can be expected due to learning curve effects, but that learning curve effects are less likely to inhibit productivity gains with process innovations (Mohnen and Hall, 2013). Less is known in the literature on the effect of organisational innovation. It is evident from this study that the effects of technological and non-technological innovations on a firm's production performance are different. The difference in the findings between technological and non-technological process innovations (i.e difference between process innovation and organisational innovation in this study) may be linked to sector differences as services and construction and mining firms are less likely to introduce process innovations, but there are no sector differences with respect to organisational innovations. It must also be noted that the use of cross-sectional data may further provide reasons for why we find a negative effect between innovation and productivity for two of the innovation types. If panel data was available for these firms we may find that the initiatives of innovating firms during the sampled period led to 'long-term' performance effects.

We believe a clear avenue for policy intervention is identified in this paper. In terms of subsidies, Policymakers have tended to pick sectors and regions as targets (Boschma, 2009). These sectors are typically in areas that are relatively new and 'exciting' industries, or where employment growth is forecasted such as in the sector of high technology. The question of a 'chicken and egg' causality concern can be inherent in this decision. For instance, innovating firms may be more likely to get subsidies as policymakers may be 'picking winners' in their distribution of subsidies. The results indicate in the counterfactual analysis that innovation has a positive effect on the productivity levels of non-innovating firms. This outlines a rationale for policy intervention that ensures inclusion of non-innovators as well as innovators for assistance, which could significantly improve market outcomes. The policy shift that is required from this evidence is that innovation policy ensures the inclusion of industries less likely to innovate. A drawback in this study is that the sectors are not at a more disaggregated level especially in the manufacturing case where it would be interesting to identify whether it is high, medium or low technology sectors that are not innovating which would help inform the specific direction for policy intervention. We note this as a particular recommendation for analysis in future studies in this area.

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3